Automation of a Distillation Column of Packed Bed for an Alcohol Solution using Arduino

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Abstract: This study demonstrates the use of Arduino to automate the operation of a distillation column binary ethanol - water as learning material used by students in the career of Chemical Engineering at the Escuela Superior Politecnica del Litoral. The main objective was to build an automated computer with the technology of arduino, in which thermocouples were used to offer students the convenience of taking temperature readings on a LCD display and in turn it allowed us to observe the level of the solution to control ignition resistance. So they were able to identify the processes that occur during the distillation unit operation automatically and manually in the Unit Operations Laboratory.

Keywords: Arduino, Thermocouples, Automation.

Automatización con Arduino de una columna de destilación de lecho empaquetado para una solución de alcohol

Resumen. Este estudio demuestra el uso de Arduino para automatizar la operación de una columna de destilación de etanol - agua binario, como material de aprendizaje utilizado por los estudiantes en la carrera de Ingeniería Química en la Escuela Superior Politécnica del Litoral. El objetivo principal fue construir un equipo automatizado con la tecnología de Arduino, en la que se utilizaron termocuplas para ofrecer a los estudiantes la facilidad de tomar lecturas de temperatura en una pantalla LCD y, a su vez, nos permitió observar el nivel de la solución para controlar la resistencia a la ignición. Así los alumnos son capaces de identificar los procesos que ocurren durante la operación de la unidad de destilación automática y manualmente en el Laboratorio de Operaciones de la Carrera.

Palabras clave: Arduino, Termocuplas, Automatización.

I. INTRODUCTION

The concept of automation is currently revolutionizing the world, today many of the procedures performed through mechanization are automated (Reyes Cortés, Cid Monjaraz, & Vargas Soto, 2013), It is from there that the mechatronic part ended, with the different use of sensors and microcontroller plates that help different operations of control. In the present study we used a solid state relay, that is the microcontroller Arduino Mega (Warren, Adams, & Molle, 2011), an alphanumeric keyboard, LCD (Wilcher,

2012), screen, a level sensor and four temperature sensors (McRoberts, 2013). Is given to much importance to using arduino (Drymonitis, 2015), because it is a relatively easy technology to implement and inexpensive.

The Arduino technology in turn has been used in a lot of automation processes, example (Nayak et al., 2016) "Separation of Aluminum and Nylon using Automation and Control Technology" who demonstrated in their study that can automate and control industrial processes at low cost using technology. In turn there are several investigations based on implementing arduino in other sectors as "Arduino Microcontroller Based Online Ambient Monitoring Using Internet of Things"(Ramya & Anbarasan, 2016), demonstrating the applicability of this technology in various areas.

The unit operations (Ratcliff, 1957) are a significant part in the study of Chemical Engineering (Marquardt, Morbach, Wiesner, & Yang, 2010), each of them consists of a series of stages with common techniques that are repeated throughout different processes of physical character. These are mainly used to perform the physical stages in the preparation of reactants, products separation, energy transfer and other applications.

The unit operations are classified according to the type of transfer, so as in mass operations where the distillation is. Distillation (Gooch, 2011) is a technique widely used in the chemical industry to separate liquid streams with two or more components based on the degree of volatility of the components the mixture, which is the basic difference with the extraction unit operation LL that today is used in many industrial processes, among these processes have oil refinement or production of alcohol, etc. Alcohol is presented as an economic and sustainable alternative when is combined with gasoline and is used as biofuel for automotive vehicles with internal combustion engines based on the spark generation vehicles. The type of alcohol used is ethanol, which can be obtained from the distillation of various fruit juice after it has been fermented for some time in order to give way to the formation of OH molecules. There are already studies as "Improving output from auxiliary distillation columns in alcoholic production" (Vyaz, Baranov, & Vyaz, 2008) where it has been shown that you can make the modernization of equipment for the production of alcohol in order to increase their efficiency and reduce resource use.

The distillation system (Zaretskii, Rusak, & Chartov, 2010) allows to obtain high purity products from mixtures of two or more components, which are to be separated according to their boiling point, in turn packed bed distillation has the advantage of getting a better mass transfer and liquid vapor contact. For a more efficient system working with recirculation of the product leaving the top of the column and for have more control over it, sensors and controllers were implemented in the various teams that make up the distillation unit.

II. IMPORTANT COMPONENTS

Arduino is compatible with a variety of components(Bell, 2013), below are detailed the ones that were used in this project, being the most important for the effect of implementation.

a. Microcontroller Arduino-Mega

Arduino (Drymonitis, 2015) is a hardware open source platform, based on a simple plate with inputs and outputs, analog and digital, used today for robotics projects due to its low cost and ease of implementation, it lets you create code in a development environment that is based on the processing programming language.

b. Temperature sensor or also called Thermocouples

The temperature sensor used for this project is DS18B20 model 4], we used three sensors also called thermocouples which on the model can be between -55 ° C to 125 ° C, and allow control of the temperature. It has 1.96 inches in length being its stainless steel material.

c. 6000w Electric Resistance

The electrical resistor (Lashley, 2010) used allows current flow of two lines, to a voltage controlled and that can be resisted by the other electronic components, this will dissipate the energy between components.

d. Relay and breaker

The solid state relay is controlled by the Arduino and can switch to open or close the electrical circuit to energize the resistor. In addition, the relay has a suitable coupler which isolates the network power electronics. Moreover, the Breaker was used as an additional security if the current exceeds the set value, thus prevents damage to the equipment.

e. Alphanumeric keyboard

With the alphanumeric keyboard was achieved the operator-equipment interaction for entering the corresponding values to the temperature.

f. LCD Screen.

We used a small LCD screen (Wilcher, 2012) which displays the value sensing thermocouples and in turn gives the team a more dynamic interface.

g. Level sensor ON-OFF

The level sensor is an electronic device (Lashley, 2010), and was used to measure the height of alcohol to be introduced within the tank the distillation column.
These types of sensors are used for process control in many industries and within this project functions as an alarm, indicating an envelope filled when the given level has been acquired, or conversely a low level alarm. 2.7 Sensor de nivel ON-OFF

III. Design and Construction

To proceed the implementation of an automation with Arduino, as a first step was held on "Design, construction and operation of a column packed bed" which is divided into 3 main phases which are shown in Figure 1, representing a diagram from inception to commissioning of the equipment in the lab(Barcia Quimí, León Munizaga, & Espol, 2016).

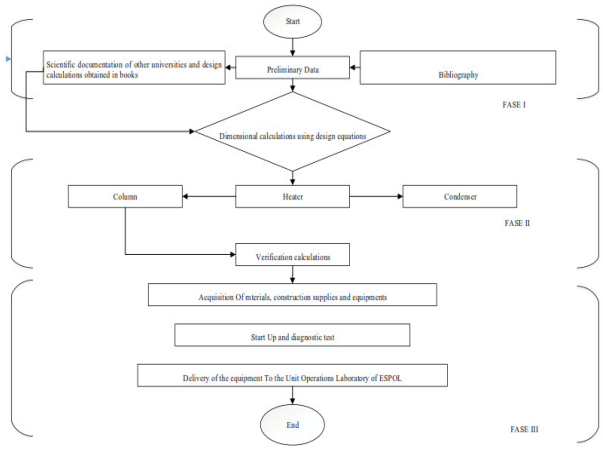

Fig. 1. Representation by a flowchart of the methodology used. (Source: Authors)

a. Fase 1. Historical analysis of similar projects.

The first phase of this project is based on a study and analysis of similar projects that have been previously performed, this study includes thesis projects, researches, specific bibliographies to the theme to define conditions and process variables. The goal is to have a clearer idea about the project and to predict what the results we would obtain or complications that may occur during the execution of the same.

b. Fase 2. Tests, calculations and verification

It proceeds with performing the necessary calculations to design the condenser, the column and the heater based on the equations identified in phase 1. In this phase we performed tests distillation binary system alcohol - water using laboratory equipment, in order to identify important variables and conditions that should work the column.

As initial sample to distill alcohol was used 20% Vol., A distiller glass and a capacitor of the same material was obtained as product alcohol 80% Vol. Working at 78 ° C, 1 atmosphere and without recirculation of the product.

c. Fase 3. Supply of materials, construction equipment and analysis of results.

The third phase can be considered as the "pillar phase" of the project, since it is the part where the increased demand for labor is concentrated. We proceed to buy the materials, which in the previous phase was identified that should be stainless steel, this material will avoid rust with the alcohol solution (industrial alcohol); in a later chapter specifications of materials to be used will be detailed. Moreover, we consider the human resource need in the electrical, electronics area, among others.

Team building begins as soon as we have the main materials such as stainless steel plates 2mm, plastic hoses, stainless steel pipes and others, to finally make a successive tests to the distillation unit and obtain a record of data in column.

IV. IMPLEMENTATION OF AUTOMATION EQUIPMENT WITH ARDUINO USE.

a. Electrical installation

The electronic system of the distillation unit consists of two parts:

The first step is to actuate the switch, if this happens it is

contacted with the contactor allowing an electric step that will ignite the pilot light. Activating a 15A breaker and 1pole and this will pass electricity to power the pump that raises the fluid to another container.

The second stage of this system is switching resistance for current flow of two lines, this will be connected to solid state relay, the same which is controlled by the electronic system project with micro-controller Arduino for that reason everything will connected to one outlet of 120V as shown in Figure 2.

The system allowed to sense all the thermocouples, a digital output commuting between high and low depending on whether the sensed value was greater than the temperature set by the keyboard, while the sensed temperature is below, the set to digital output is high and therefore the relay is activated allowing current flow to the resistance, thus maintaining the stable linked with the temperature at a point. The system has communication with the three thermocouples installed (lower, middle and upper), it is proposed in section 4.2 the detail of the connections of the microcontroller for proper use.

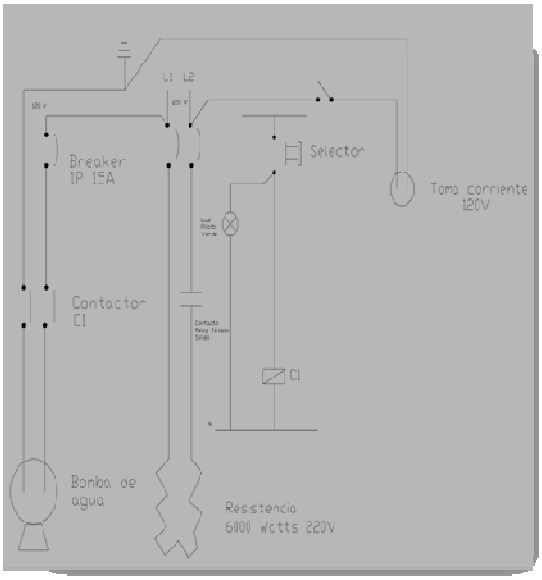

Fig. 2. Diagram Force and Pump Control and Resistance (Source: Authors)

a. Electronics Installation - Arduino Microcontroller.

The electronic system installed in the Distillation Unit consists of 6 major components: a solid state relay, a microcontroller Arduino Mega, an alphanumeric keyboard, an LCD screen, a level sensor and four temperature sensors. The circuit has 3 defined entries which will be discussed below: an alphanumeric keyboard that allows the user to set the desired temperature within the heater; the level sensor that is responsible for sending logical levels of voltage to the microcontroller Arduino depending on the amount of liquid inside the heater and finally the sensors of digital and submersible temperature (McRoberts, 2013) located in different points of interest in Unit Distillation, the same as establish a connection using the communication protocol 1-Wire (©2016 Arduin, 2016) with the Arduino and thus each sensor sends real-time corresponding to the information of middle temperature.

The circuit outputs correspond to the LCD display and solid state relay, in the screen the temperatures detected are shown and also indicates whether the resistance is on or off. The solid state relay performs the function of allowing or preventing the passage of current as the signal to send the Arduino microcontroller, on or off the resistance heater located inside. In Figure 3 interconnection between components of the electronic system is shown.

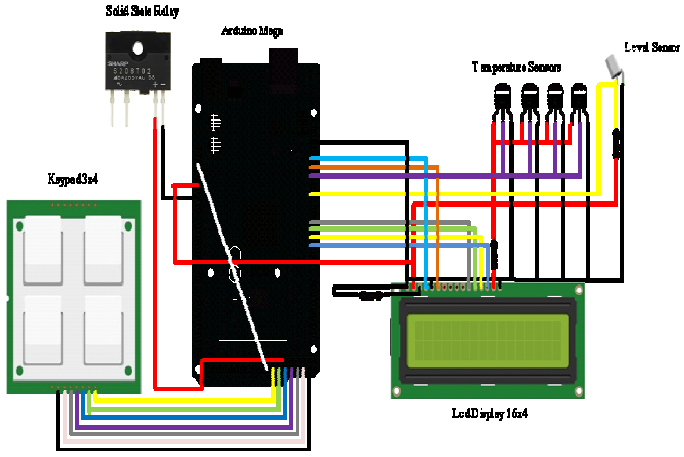

Fig. 3. Electric diagram (Source: Authors)

b. Controller of the sensor through 1-Wire protocol.

The 1-Wire protocol has been called MicroLan (©2016 Arduin, 2016) and allows sending and receiving data, which

in this case we have used to communicate with the temperature sensor, detailed in the "1-Wire Coding, Communication" the section code used for stabilize the communication.

1) Coding, 1-Wire communication.

```
 if ( !ds.search(addr)) {
   Serial.println("No more addresses.");
   Serial.println();
   ds.reset_search();
   delay(250);
   return;
 }

 Serial.print("ROM =");
 for( i = 0; i < 8; i++) {
   Serial.write(' ');
   Serial.print(addr[i], HEX);
 }

 if (OneWire::crc8(addr, 7) != addr[7]) {
     Serial.println("CRC is not valid!");
     return;
 }
// the first ROM byte indicates which chip
 switch (addr[0]) {
   case 0x10:
     Serial.println("  Chip = DS18S20");  // or old DS1820
     type_s = 1;
     break;
   case 0x28:
     Serial.println("  Chip = DS18B20");
     type_s = 0;
     break;
   case 0x22:
     Serial.println("  Chip = DS1822");
     type_s = 0;
     break;
   default:
     Serial.println("Device is not a DS18x20 family device.");
     return;
 }

 ds.reset();
 ds.select(addr);
 ds.write(0x44, 1);         // start conversion, with //parasite
power on at the end.

 // Convert the data to actual temperature
 // because the result is a 16 bit signed integer, it should
 // be stored to an "int16_t" type, which is always 16 bits
 // even when compiled on a 32 bit processor.
 int16_t raw = (data[1] << 8) | data[0];
 if (type_s) {
   raw = raw << 3; // 9 bit resolution default
   if (data[7] == 0x10) {
     // "count remain" gives full 12 bit resolution
     raw = (raw & 0xFFF0) + 12 - data[6];
   }
 } else {
   byte cfg = (data[4] & 0x60);
   // at lower res, the low bits are undefined, so let's zero
them
   if (cfg == 0x00) raw = raw & ~7;  // 9 bit resolution, 93.75
ms
   else if (cfg == 0x20) raw = raw & ~3; // 10 bit res, 187.5
ms
   else if (cfg == 0x40) raw = raw & ~1; // 11 bit res, 375 ms
   //// default is 12 bit resolution, 750 ms conversion time
 }
 celsius = (float)raw / 16.0;
 fahrenheit = celsius * 1.8 + 32.0;
```

c. Construction of the Support Structure.

In order for the column to work in an optimal way, it was essential to build a support structure based on the research " Experimental evaluation of a modified fully thermally coupled distillation column" (Hwang, Kim, & Kim, 2010), where it was performed an experimental distillation system using thermocouples . For this design it is important to choose a material of high quality, because it is where all the distillation unit will be supported. In this case we chose to work with iron because it is a strong and inexpensive material that would easily be found in the ecuadorian market, as a disadvantage we have that this is a material that can corrode, but we proceeded to place a layer of anti-corrosive paint Pintuco on its surface to avoid this to happen. The above mentioned, it is shown in Figure 4.

Fig. 4. Support Structure Distillation Unit (Source: Diseño, Construcción y Puesta en Marcha de una Columna de Destilación de Lecho Empacado para una Solución de Alcohol, p. 91)

V. CONCLUSIONS

Through this design it is concluded that the use of arduino is feasible for automation of processes carried out manually, in different sectors.

For this article the implementation of arduino stands out as programmable microcontroller, able to send and receive signals from each of the installed sensors, becoming the processes industrial into technological, that were carried out manually and creating a computer-operator friendly interface. It is fused technology and industrial processes to generate a paper describing the design and implementation of a distillation column packed bed for an alcohol solution merges.

We identified components that serve to automate Distillation Unit and proceeded to define the design variables. The main equipment of the unit is the distillation column packed bed whose dimensions are 3.94 feet tall x 3.5 "diameter and whose filling consists of approximately 120 glass beads. Distillation Unit is in the ability to treat 31.12 lb · h-1 mixture of ethanol. Water and introducing the mixture to 20% Vol product can be obtained with a concentration of 80% - 92% ethanol Vol.

Referencing other studies for example (Shirsat, Dawande, & Kakade, 2013) and "Process Simulation in Chemical Engineering" (Chaves, López, Zapata, Robayo, & Niño, 2016), the simulation of the distillation operation in "CHEMCAD", using data such as the concentration at which the feed mixture is performed (20% Vol.), Pressure (1 atm) which is desired to operate the mixture, the type of capacitor used and the reflux ratio (3). The data obtained from the simulation have an error of 15% - 0% compared to those made manually with the design equations.

Through tests, the optimum conditions to which must operate column for a high concentration of an alcohol solution were determined. However, it is important to consider the time spent in practice as wanting to give a concentration of 92% vol. In solution will need at least 3 hours of distillation. Therefore, the longer, the higher the concentration and vice versa less time, a lower concentration is obtained. This equipment is designed for laboratory practice with various types of solutions knowing their boiling points.

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